2026 Student Achievement Award Nominee

Owen Rempel

Evaluating the Performance of Nano-Metakaolin on the Rheological and Mechanical Properties of Cold-Weather 3D Printed Concrete

Three-dimensional printed concrete (3DPC) is an emerging construction technology with the potential to improve productivity, reduce construction time, and enhance project sustainability. However, limited research exists on the performance of 3DPC in cold-weather conditions and on the use of certain nanomaterials within these applications, creating barriers to broader adoption in colder climates.

To address these knowledge gaps, Owen's research examined the performance of 3DPC under cold-weather conditions ranging from -5°C to 5°C and evaluated the effects of nano-metakaolin binder replacement on material performance. Fresh-state properties, including flowability, yield stress, setting time, and printing time window, were assessed alongside hardened-state properties such as compressive strength, interlayer bond strength, and microstructural quality. To support future practical application, all nano-metakaolin, cement, and aggregate materials were sourced within Canada.

Four custom concrete mixtures were developed for the study, including a control mix and three mixes containing varying levels of nano-metakaolin replacement. Each mixture was produced and tested under controlled cold-weather conditions, with printed specimens cured for 28 days in an environmental chamber before evaluation.

The results demonstrated that all four mixtures could be successfully used in cold-weather conditions, with the nano-metakaolin mixtures showing the strongest overall performance. Nano-metakaolin significantly improved microstructural quality and fresh-state properties. While the anticipated improvements in strength were not fully realized, this was attributed in part to limitations associated with manual printing compared to machine printing. Overall, the findings demonstrated significant promise for nano-metakaolin in cold-weather 3DPC applications, with the 4% replacement mix identified as the preferred option for future use.

Owen's research contributes to a broader multi-year investigation into three-dimensional printed concrete at the University of Manitoba and advances understanding of how innovative construction materials can be adapted for cold-weather environments.